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High energy mode locked fiber oscillators for high contrast, high energy petawatt laser seed sources

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Abstract: In a high-energy petawatt laser beam line the ASE pulse contrast is directly related to the total laser gain. Thus a more energetic input pulse will result in increased pulse contrast at the target. We have developed a mode-locked fiber laser with high quality pulses and energies exceeding 25nJ. We believe this 25nJ result is scalable to higher energies. This oscillator has no intra-cavity dispersion compensation, which yields an extremely simple, and elegant laser configuration. We will discuss the design of this laser, our most recent results and characterization of all the key parameters relevant to its use as a seed laser.

Our oscillator is a ring cavity mode-locked fiber laser [1]. These lasers operate in a self-similar pulse propagation regime characterized by a spectrum that is almost square. This mode was found theoretically [2] to occur only in the positive dispersion regime. Further increasing positive dispersion should lead to increasing pulse energy [2]. We established that the positive dispersion required for high-energy operation was approximately that of 2m of fiber. To this end, we constructed a laser cavity similar to [1], but with no gratings and only 2m of fiber, which we cladding pumped in order to ensure sufficient pump power was available to achieve mode-locked operation. A schematic of the laser is shown in figure 1 below. This laser produced low noise 25nJ pulses with a broad self-similar spectrum (figure 2) and pulses that could be de-chirped to <100fs (figure 3).

Pulse contrast is important in peta-watt laser systems. A major contributor to pulse contrast is amplified spontaneous emission (ASE), which is proportional to the gain in the laser chain. As the oscillator strength is increased, the required gain to reach 1PW pulses is decreased, reducing ASE and improving pulse contrast. We believe these lasers can be scaled in a stable fashion to pulse energies as high as 100nJ and have in fact seen 60nJ briefly in our lab, which is work still in progress. At this level, even if the pulses are not perfect, post-oscillator pulse cleaning can be used to create a clean high energy pulse for injection into a peta-watt laser beam line.

References

- 1) J. R. Buckley, F. W. Wise, F. O. Ilday, T. Sosnowski, "Femtosecond fiber lasers with pulse energies above 10 nJ," *Opt Lett* **30**, 1888-1890 (2005).
- 2) F. O. Ilday, "Theory and practice of high-energy femtosecond fiber lasers," Ph.D. Dissertation, Cornell University, 2004

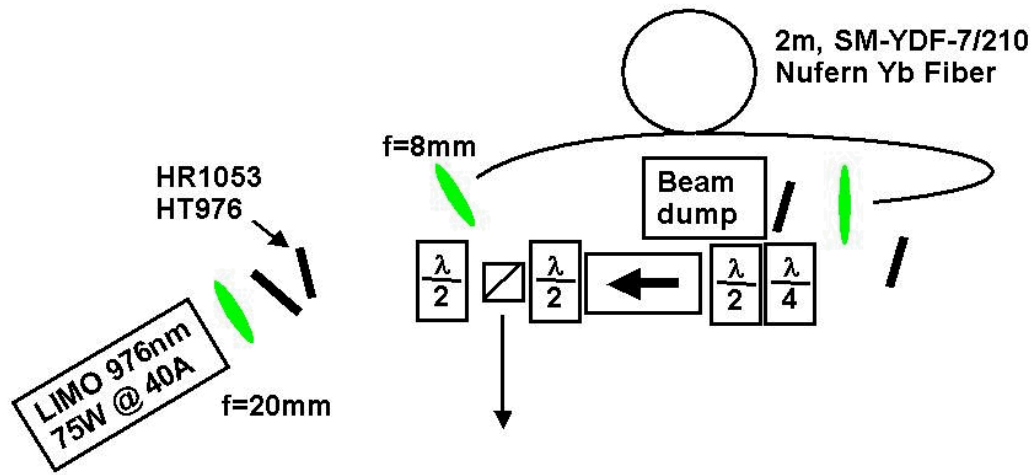


Figure 1: Schematic of grating-less 25nJ fiber oscillator

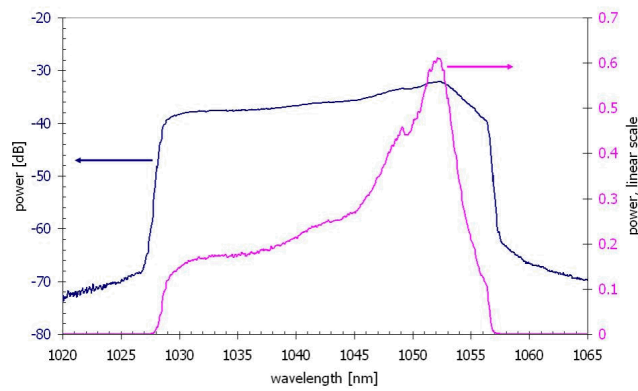


Figure 2: Spectrum of oscillator at 25nJ

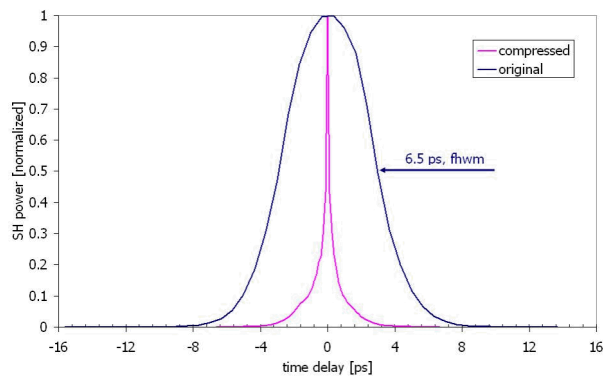


Figure 3: Auto-correlation trace of oscillator pulses before and after de-chirping